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The prompt photon photoproduction at THERA [1]

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Abstract

We present NLO QCD predictions for the prompt photon photoproduction at the THERA, and compare them with results for the HERA collider.

1 Introduction

Photoproduction of photons with large transverse momentum, $p_T \gg \Lambda_{QCD}$, in ep collisions, $ep \to e\gamma X$, is an important test of pQCD. In particular it allows to probe the photonic content of the photon [1]. This process, called also the prompt photon photoproduction or the Deep Inelastic Compton (DIC) scattering, was measured at the HERA collider by the ZEUS [2, 3, 4] and H1 [5] Collaborations. In this note we compare the potential of the THERA and HERA colliders in measuring the DIC process. The predictions of NLO QCD calculations for the photoproduction of *non-isolated* prompt photon at HERA and THERA energies are presented.

In the present experimental analyses of the prompt photon production at HERA the hadronic energy detected close to the final photon has been restricted, and therefore one can say that the final photon is *isolated*. The NLO calculations for the DIC process with isolated photon at the HERA collider [6, 7] give reasonably good description of the ZEUS data for the p_T distribution [4]. For the rapidity distribution the results are in good agreement with data at rapidities $\eta_\gamma > 0.1$, however they lie below data at rapidities $\eta_\gamma < 0.1$ (the difference is $\sim 30\%$) [4]. For comparison with results for non-isolated photon discussed in this paper, we present also our predictions for isolated photon at HERA together with the ZEUS data [4].

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2 The NLO cross section

The cross section for the photoproduction in the ep collision can be calculated using the equivalent photon approximation [8]:

$$d\sigma^{ep} = \int G_{\gamma/e}(y) d\sigma^{\gamma p} dy, \tag{1}$$

where $y = E_\gamma/E_e$ is (in the laboratory frame) a fraction of the initial electron energy taken by the photon. The (real) photon distribution in the electron we take in the form:

$$G_{\gamma/e}(y) = \frac{\alpha}{2\pi}\{\frac{1+(1-y)^2}{y}\ln[\frac{Q^2_{max}(1-y)}{m_e^2 y^2}] - \frac{2}{y}(1-y-\frac{m_e^2 y^2}{Q^2_{max}})\}, \tag{2}$$

with m_e being the electron mass, and $Q^2_{max} = 1$ GeV^2 (used both for the HERA and THERA collider)

We consider now the production of a large-p_T photon in the $\gamma p \to \gamma X$ scattering. The lowest order (Born) contribution to the cross section comes from the Compton process on the quark, $\gamma q \to \gamma q$. In the NLO calculation one takes into account α_s corrections to the Born process: the virtual gluon exchange and real gluon emission, together with the subprocess $\gamma g \to \gamma q \bar{q}$. The collinear singularities, which appear in these corrections, are subtracted and shifted into corresponding parton densities or fragmentation function. The remaining corrections, without singularities, constitute the so called K-factor.

The initial photon may interact directly with the parton from the proton (as in the Born process) or may interact as the resolved one via its partons. Analogously, the observed final photon arise directly from hard partonic subprocesses (as in the Born process) or arise from fragmentation processes in which q or g 'decays' into γ.

The NLO cross section for the photon production in γp collision can therefore be written in the following form [2]:

$$E_\gamma \frac{d^3\sigma^{\gamma p\to\gamma X}}{d^3p_\gamma} = \sum_q \int dx f_{q/p}(x,\bar{Q}^2) E_\gamma \frac{d^3\sigma^{\gamma q\to\gamma q}}{d^3p_\gamma} + \sum_b \int dx f_{b/p}(x,\bar{Q}^2)\frac{\alpha_s(\bar{Q}^2)}{2\pi^2\hat{s}} K_b + \tag{3}$$

$$+ \sum_{ab} \int dx_\gamma \int dx f_{a/\gamma}(x_\gamma,\bar{Q}^2) f_{b/p}(x,\bar{Q}^2) E_\gamma \frac{d^3\sigma^{ab\to\gamma d}}{d^3p_\gamma} + \tag{4}$$

$$+ \sum_{bc} \int \frac{dz}{z^2} \int dx f_{b/p}(x,\bar{Q}^2) D_{\gamma/c}(z,\bar{Q}^2) E_\gamma \frac{d^3\sigma^{\gamma b\to cd}}{d^3p_\gamma} + \tag{5}$$

$$+ \sum_{abc} \int \frac{dz}{z^2} \int dx_\gamma \int dx f_{a/\gamma}(x_\gamma,\bar{Q}^2) f_{b/p}(x,\bar{Q}^2) D_{\gamma/c}(z,\bar{Q}^2) E_\gamma \frac{d^3\sigma^{ab\to cd}}{d^3p_\gamma} + \tag{6}$$

$$+ \int dx f_{g/p}(x,\bar{Q}^2) E_\gamma \frac{d^3\sigma^{\gamma g\to\gamma g}}{d^3p_\gamma}, \tag{7}$$

where x_γ (x) stands for the photon (proton) momentum fraction taken by the a (b)-parton, and z is the momentum fraction of the c-parton fragmenting into photon. The

[2]Note, that in our approach the parton densities in the photon and parton fragmentation into photon are treated as quantities of order α_{em} [7], while e.g. in [6] they are assumed to be of order α_{em}/α_s. This leads to different set of subprocesses included in NLO calculations in both approaches.

$f_{a/\gamma}$, $f_{b/p}$ and $D_{\gamma/c}$ are the parton densities in the photon, parton densities in the proton and parton fragmentation into photon, respectively.

The first and the second term in eq. (3) correspond to the Born contribution and to the K-factor, respectively. The three terms (4, 5, 6) are due to various resolved photon subprocesses, with resolved initial or/and final photon. The last term (7) stands for the contribution of the box diagram, $\gamma g \to \gamma g$. The box diagram is of NNLO-type (as it is the double resolved photon processes), nevertheless we take it into account in our NLO calculation, because it is known that they give a sizable contributions, see e.g. [7].

3 The results

We present NLO QCD results for the DIC cross section at HERA and THERA energies. For THERA we assume $E_e = 250$ GeV and $E_p = 920$ GeV. For HERA we take $E_e = 27.5$ GeV and $E_p = 820$ GeV [3] used in the ZEUS [2, 3, 4] and H1 [5] measurements. The GRV NLO parametrizations for the parton distributions in the proton [9] and photon [10], and parton fragmentation into photon [11] are used. The renormalization/factorization scale is assumed equal to the transverse momentum of the final photon, $\bar{Q} = p_T$. The calculations are performed for four massless quarks, $N_f = 4$, and $\Lambda_{QCD} = 320$ MeV.

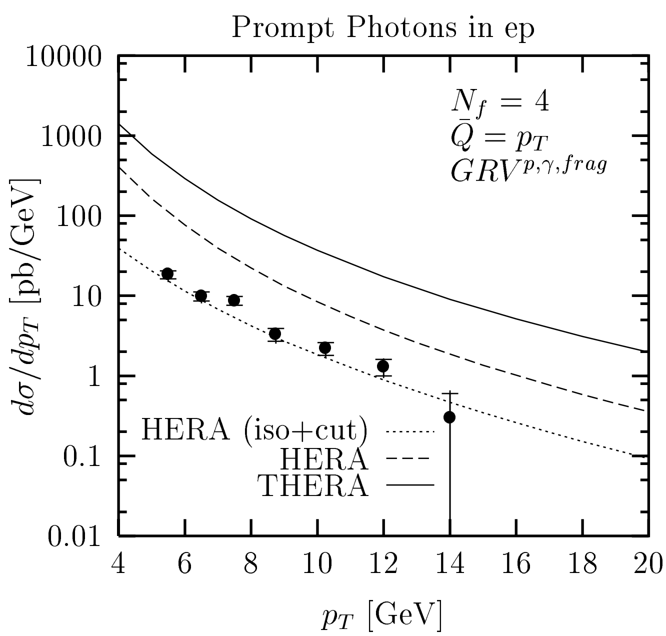

Figure 1: The p_T distribution for the inclusive prompt photon production. The rapidity is taken in the range $-0.7 \leq \eta_\gamma \leq 0.9$. The NLO results for THERA (solid line) and HERA [7] (dashed line) are shown. For comparison also results for isolated photons with an additional cut ($0.2 \leq y \leq 0.9$) as measured by the ZEUS Collaboration [4] are plotted together with the NLO predictions [7] (dotted line).

In fig. 1 the cross section $d\sigma/dp_T$ is presented for $4 \leq p_T \leq 20$ GeV and $-0.7 \leq \eta_\gamma \leq 0.9$. The results strongly depend on p_T: the cross section decreases by three

[3]not 920 GeV

orders of magnitude when the p_T increases from 4 to 20 GeV. The predictions for the THERA collider are larger than for HERA, 3.5 to 5.5 times for p_T from 4 to 20 GeV. Note that the isolation and additional cuts applied by the ZEUS group [4] at HERA reduce the cross section by a factor of 10 (4) at $p_T = 4$ (20) GeV.

The cross section $d\sigma/d\eta_\gamma$ for $5 \leq p_T \leq 10$ GeV is presented in fig. 2. The range of accessible rapidities is extended and the value of the cross section is much higher for the THERA collider in comparison with predictions for HERA. In the central rapidity region, $-1 \leq \eta_\gamma \leq 1$, (where the ZEUS data [4] are shown) the results obtained for THERA are $\sim$ 2 - 5.5 times larger than for HERA.

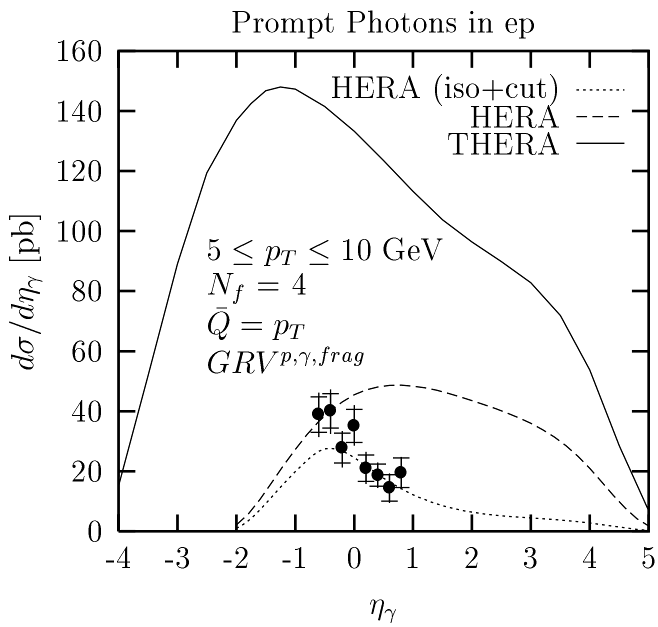

Figure 2: The η_γ distribution for $5 \leq p_T \leq 10$ GeV. The NLO results for THERA (solid line) and HERA [7] (dashed line) are shown. For comparison the ZEUS Collaboration data [4] and the NLO predictions [7] (dotted line) for isolated photons with additional cuts ($0.2 \leq y \leq 0.9$, $-0.7 \leq \eta_\gamma \leq 0.9$) are presented.

4 Summary

We have presented results of NLO calculation for the non-isolated prompt photon photoproduction at the THERA and HERA colliders. The predictions for THERA are a few times larger than for HERA in a wide range of transverse momentum and rapidities. This can allow to perform much more precise measurements than the present ones and e.g. in testing the parton densities in the photon. For a comparison the current data and predictions for isolated photon at HERA are also shown.

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